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(54) Compressor

(57) A two-stage gas compressor 1 comprises opposed cylinders 31, 41 within which are reciprocable pistons 30, 40 respectively, the pistons being secured to opposite ends of a lead screw 20 which is moved axially by an axially-captive nut 14 forming part of the rotor assembly of an electric motor 16. Motor 16 is provided with the characteristics of a D.C. electric motor and the pistons 30, 40 are each driven into abutment with the pertaining cylinder head 32, 42 which abutment is sensed by a control unit which reverses the drive to the motor 16. Each piston is provided with a self-lubricating leak-tight ring seal 35, 45 and each cylinder head has inlet and outlet valves 33, 34 and 43, 44 respectively also provided with leak-tight seals, the piston crowns being similarly shaped to the pertaining cylinder heads 32, 42 so that the chamber volumes at piston top dead centre are minimised. The compressor 1 operates relatively slowly due to the D.C. motor characteristics and achieves high compression ratios without gas contamination by lubricant since the seals are all self-lubricating.

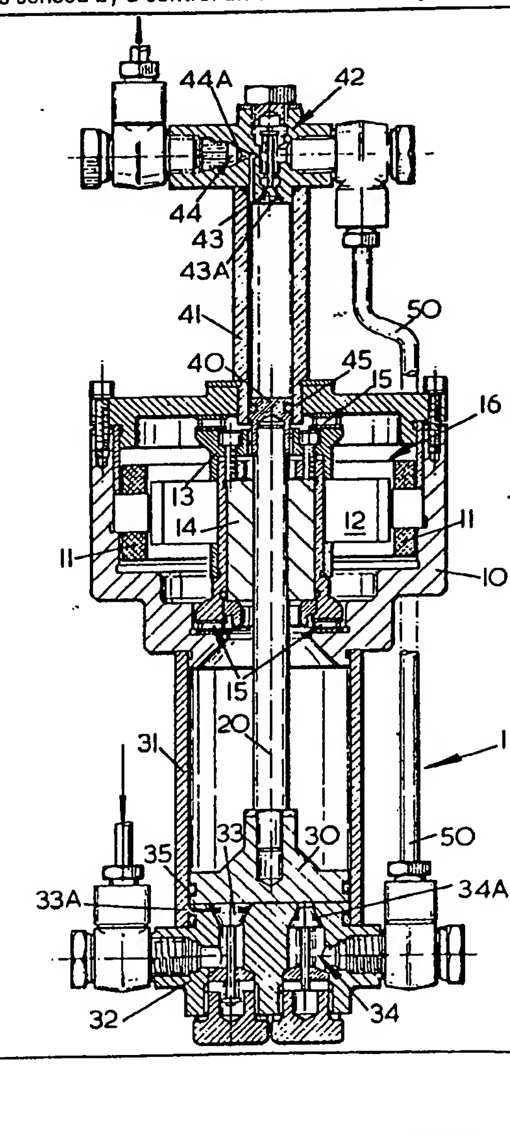

FIG 1

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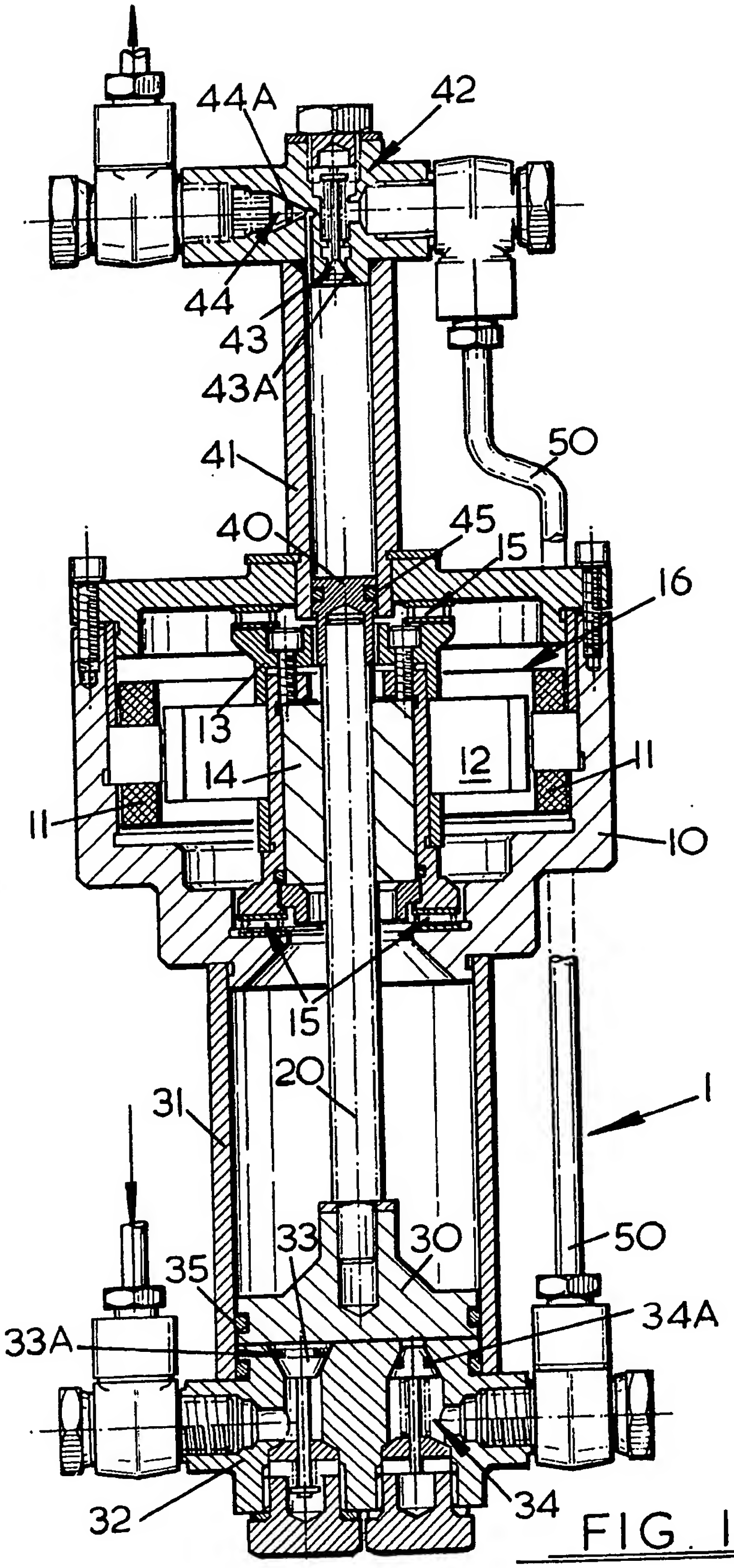

FIG. 1

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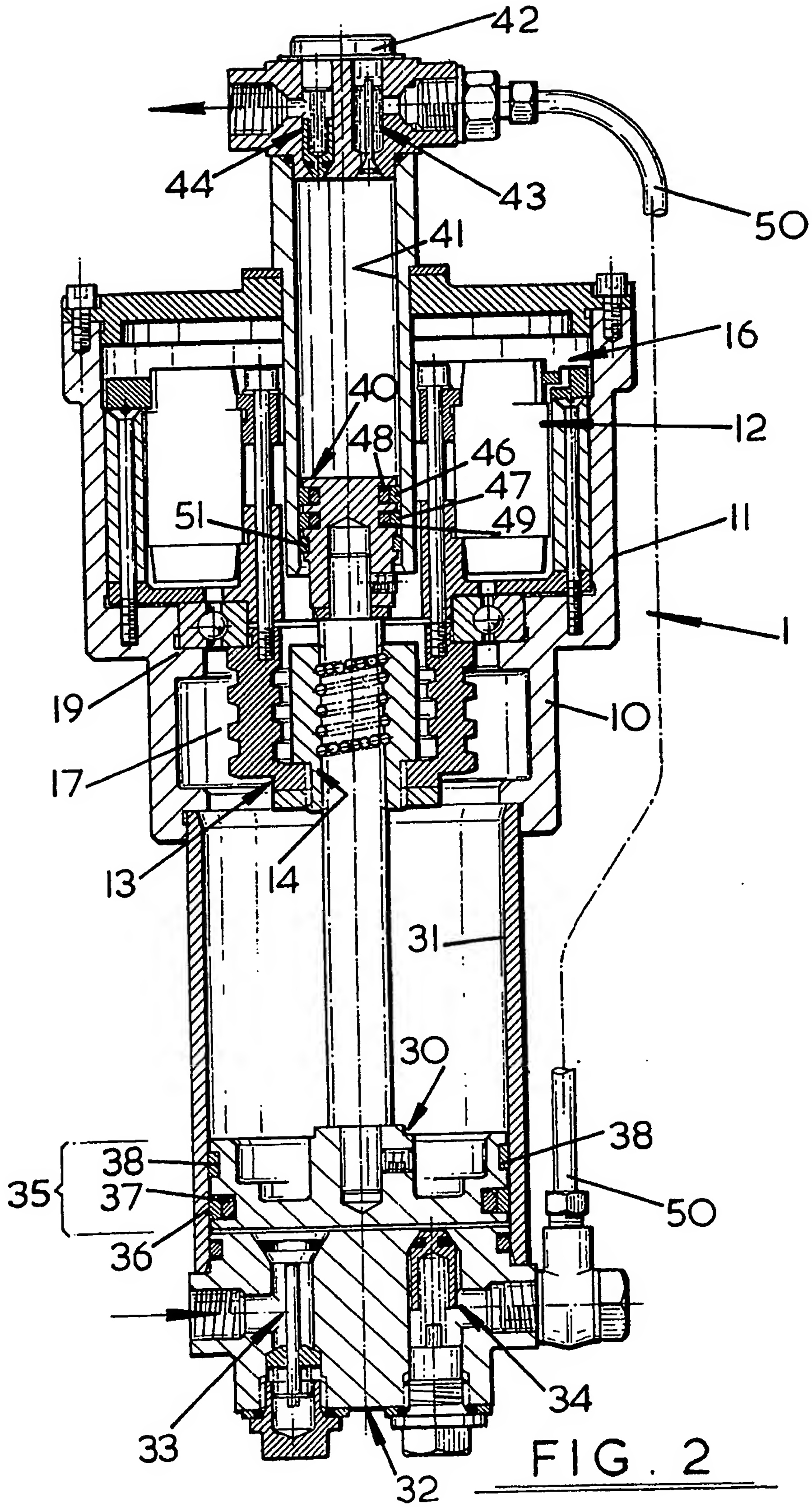

FIG. 2

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SPECIFICATION
Compressor

This invention relates to a compressor.

More particularly, the invention relates to a high pressure, low capacity compact gas compressor suitable for laboratory, installed or portable applications. It is intended for use where small capacity, high pressure gas is needed to a high standard of purity. A typical application would be to supply the air for cryogenic cooling systems of electronic devices.

Conventionally, high pressure gas is obtained from gas bottlers who supply the user with gas in steel cylinders. Alternatively, the gas is compressed on the users premises by a conventional compressor, housed normally in a special room or hut for safety or acoustic reasons. The bottled gas method implies storage, handling, safety and logistic problems. The in-house compressor normally requires specialist maintenance and operating skills, is usually noisy and is unpopular with users because of danger and dirt reasons.

In a conventional positive displacement compressor the piston is driven up and down the cylinder at high speed by a rod connected to the pin of a crank shaft, the compression ratio in the first instance being determined by the ratios of volumes at the bottom and top of the stroke. The volume at the top is required to ensure that a working clearance exists between the piston crown and the cylinder head, since contact between them at the speeds involved would cause mechanical damage. Other factors such as piston leakage and heating due to the speed of compression reduce the system efficiency. To achieve high compression ratios 3—4 stage machines with interstage cooling are required. The high speeds employed in such machines are required to overcome the effect of piston ring leakage since conventional piston rings have an axial split, and in turn impose a need for oil lubrication to overcome friction effects, with gas contamination as a consequence.

It is an object of the present invention to obviate or mitigate the problems outlined above when small demands and high pressures are required.

According to the present invention there is provided a gas compressor comprising a housing defining a compression chamber, a piston reciprocable within said chamber and drivingly connected to one end of a lead screw which co-operates with and is linearly driven by a nut forming part of the rotor assembly of an electric motor.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is an elevational view, in cross-section of the first embodiment of a compressor made in accordance with the present invention; and

Fig. 2 is a similar view of a second embodiment.

Referring to Fig. 1 of the drawings, a compressor 1 comprises a motor housing 10 in which there are located stator windings 11 of a D.C. electric motor 16. The rotor assembly of the motor 16 includes a hollow armature 12 rigidly connected to a roller nut 14 by a rigid nut cage 13, the rotor assembly being retained within the motor housing 10 by a pair of opposed thrust bearings 15 of the roller type.

A lead screw 20 is drivingly engaged by the nut 14 and is driven axially on rotation of the nut 14. One end of the lead screw 20 is secured to a first, large piston 30 movable within a first cylinder 31 which defines a low-pressure compression chamber. The cylinder 31 is fitted at one end to the motor housing 10 and is closed at its other end with a cylinder head 32 having a non-return inlet valve 33 and a non-return low-pressure outlet valve 34. The piston 30 is provided with ring seals 35 which are self lubricating and leak tight and the heads of valves 33, 34 are likewise provided with leak tight ring seals 33A, 34A respectively so that the three seals together render the low-pressure compression chamber leak tight.

On the opposite side of the motor housing 10 a second, high pressure cylinder 41 is fitted within which a second, small piston 40 is movable. The second piston 40 is secured to the other end of the lead screw 20 and has a ring seal 45 which is also self lubricating and leak tight. The cylinder 41 is closed by a cylinder head 42 having a non-return high pressure outlet valve 44 and a non-return high pressure inlet valve 43 connected to the low-pressure outlet valve 34 of the low-pressure stage by means of an inter-stage pipe 50. The heads of valves 43, 44 are provided with leak-tight ring seals 43A, 44A respectively so that together with seal 45 the high pressure chamber is rendered leak-tight.

A control unit (not shown) controls the speed and direction of rotation of the electric motor 16 and the compressor 1 operates as follows.

When the motor 16 is turned in one direction the large piston 30, is driven towards the cylinder head 32 forcing the gas contained in the cylinder 31 to be compressed into the small cylinder 41 via the external connecting pipe 50, return flow being prevented by the non-return valves 34, 43 in both cylinder heads.

The large piston 30 is driven until it is in mechanical contact with its cylinder head 32. When this point is reached the motor 16 is reversed and the small piston 40 is driven from the fully back position (as illustrated) towards the small cylinder head 42. In so doing, the gas previously compressed at low pressure into the small cylinder 41 is further compressed to a high level as determined by opening of the outlet valve 44 and the nature of the apparatus down stream of valve 44.

By this method of driving the pistons to be in mechanical contact with the cylinder heads, very high compression ratios can be achieved and hence an overall ratio of 200:1 can be obtained in

two stages, in a machine of relatively small size. In order to maximise the compression ratio of each compression chamber the pertaining piston crown and cylinder head have similar shapes, substantially planar as illustrated, so that the volume of each chamber with the piston at the top of its stroke is minimised and approaches zero to within the limits of practicality.

The compressor 1 is relatively slow acting by virtue of the operational characteristics of the D.C. motor 16 which is preferably series wound so that in relation to a piston undertaking a compression stroke maximum speed of piston movement is obtained initially when the chamber pressure is lowest and as the stroke continues and chamber pressure increases the speed of motor 16 reduces until a stall condition is approached towards the end of the stroke. At the end of the stroke the motor 16 reaches the stall condition (since the piston abuts the cylinder head) and it is at this point that the motor control unit reverses the motor drive. Motor 16 therefore requires to be capable of withstanding, electrically, the stall condition. However in view of the fact that piston speed progressively reduces towards zero due to motor loading caused by compression chamber pressure increase there is virtually no mechanical shock loading when the piston enters into abutment with the cylinder head.

By virtue of the slow speed of compression there is practically no compression heating of the gas; the need to provide ancillary lubrication of the piston ring seals is eliminated, and the compressor is practically silent in operation. The piston ring seals are preferably made of plastics material and annular without any axial split in order to be both self lubricating and leak tight. .

In the Fig. 1 embodiment nut 14 is of the self centering roller screw type so that bearings 15 need only accommodate thrust forces.

Turning now to the Fig. 2 embodiment the compressor 1 is substantially as described above with reference to Fig. 1 but certain details are illustrated with greater particularity, motor 16 incorporates a useful modification to be described, and the area of high pressure piston 40 is increased (with corresponding reduction of the overall compression ratio of the compressor 1) in order to accommodate valves 43, 44 side-by-side in the cylinder head 42 as against the arrangement shown in Fig. 1.

With reference to low-pressure piston 30 it will be seen that seal 35 comprises a ptfe slipper ring 36 resiliently urged radially outwardly against the wall of cylinder 31 by a rubber O-ring 37 and, axially behind slipper ring 36, a ptfe wear ring 38.

With reference to high pressure piston 40 it will be seen that seal 45 comprises a pair of ptfe slipper rings 46, 47 respectively resiliently urged radially outwardly against the wall of cylinder 41 by a rubber O-ring 48, 49 and, axially behind slipper rings 46, 47, a ptfe wear ring 51.

In Fig. 2 the rotor assembly of motor 16 comprises hollow armature 12 drivingly connected to nut 14 by cage 13 but in this embodiment cage 13 comprises a semi-rigid portion 17 formed in bellows fashion from beryllium copper or spring steel for the purpose of absorbing any mechanical shock loading which may arise from either piston 30, 40 entering into abutment with its pertaining cylinder head 32, 42. The degree of resilience of portion 17 is such that it does not compress due to the effects of gas pressure alone in either compression chamber. Also, nut 14 is of the recirculating ball screw type which is not self centering and accordingly the rotor assembly is carried rotatably by a deep-groove ball bearing 19 instead of opposed thrust bearings 15.

It will now be appreciated that by careful attention to dimensions, clearances and materials very low leakages at the valves and pistons can be realised in either of the described embodiments, and since each compressor is, by virtue of its design, relatively slow acting, heating and piston lubrication problems do not exist. Thus the gas is not contaminated in the compressor and extensive gas cleaning plant is not required.

The power to the motor may be either switched on or off or modulated by a pressure sensing control system but the use of a modulating control could eliminate the need for further pressure regulating control valves.

The motor control unit although not shown may include a system for sensing the piston/cylinder-head contact condition based on a tachometric or an electrical current sensing circuit since the stator current rises significantly as the stall condition is approached, the output from this being used to control the power to the nut drive motor. The electric motor 16 in its simplest form is of the permanent magnet D.C. type either of the conventional brush type or the brushless type but it could alternatively be of the A.C. type with suitable dynamic control to provide it with D.C. motor characteristics which are as previously described and in particular provide a relatively wide speed range which is useful in maximising overall efficiency of the compressor.

By way of example compressors in accordance with the present invention can provide gas flow rates of the order of 2 litres/min at pressures of the order of 2000—3000 psi, operating with a cycle period of about 5 seconds and having a power consumption of the order of 30 watts derived from a 24 volt D.C. electrical supply.

CLAIMS

1. A gas compressor comprising a housing defining a compression chamber, a piston reciprocable within said chamber and drivingly connected to one end of a lead screw which co-operates with and is linearly driven by a nut forming part of the rotor assembly of an electric motor.

2. A compressor as claimed in claim 1, comprising a second housing defining a second compression chamber, a second piston being reciprocable within said second chamber and being drivingly connected to the other end of said

lead screw, conduit means interconnecting the two compression chambers and arranged so that the compressor is a two-stage compressor.

3. A compressor as claimed in either preceding claim, wherein the or each piston incorporates a self-lubricating leak-tight ring seal.

4. A compressor as claimed in any preceding claim, wherein said electric motor has the characteristics of a D.C. electric motor.

5. A compressor as claimed in claim 4, wherein the electric motor is controlled by a control unit to reverse its drive direction on abutment of the or either piston with the pertaining cylinder head.

6. A compressor as claimed in any preceding claim, wherein the or each compression chamber has a cylinder head with a shape similar to the crown of the pertaining piston so that the volume of the or each chamber with the pertaining piston at the top of its stroke is minimised.

7. A compressor as claimed in any preceding claim, wherein the rotor assembly of said electric motor incorporates a rigid cage interconnecting said nut with the armature of said motor.

8. A compressor as claimed in any one of claims 1—6, wherein the rotor assembly of said electric motor incorporates a semi-rigid cage interconnecting said nut with the armature of said motor.

9. A compressor as claimed in any preceding claim, wherein said nut is of the recirculating ball type.

10. A compressor as claimed in any one of claims 1—8, wherein said nut is of the roller screw type.

11. A compressor as claimed in claim 1 and substantially as hereinbefore described with reference to either of the embodiments illustrated in the accompanying drawings.

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